Journal of Agricultural Research Advances
ISSN: 2582-7227

Research Article
Open Access

# Performance evaluation of cabbage (*Brassica oleracea* L.*Var.Capitata)* with irrigation scheduling and nitrogen fertilizer

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Received on: 26/11/2020 Accepted on: 05/01/2021 Published on: 18/01/2021

## ABSTRACT

**Aim:** The study was aimed to investigate the effect of irrigation schedules and nitrogen fertilizer application rate on growth and productivity cabbage at Buyo Kachama Kebele Seka woreda Jimma.
**Materials and Methods:** Three irrigation scheduling (3 days, 6 days and 9 days) and five nitrogen fertilizer levels (0, 23, 46, 69 and 92 kg/ha) were used with Randomized Complete Block Design (RCBD) in 3x5 factorial arrangements with three replications experiments and one farmer practice using Copenhagen market variety of cabbage.
**Results:** The highest marketable yield was recorded at 92 kg $ha^{-1}$ nitrogen fertilizer rate and 9 days irrigation schedules, lowest unmarketable yield, highest total head yield, biggest whole fresh weight, biggest head diameter, highest head height, highest plant height, wider plant spread, highest water use efficiency and nitrogen recovery was recorded at 9 days irrigation schedules and 23 kg/$ha^{-1}$ nitrogen fertilizer rate, which was statically similar with 9 days irrigation scheduling and 46 kg/ha nitrogen fertilizer rate. Harvest index significantly affected by nitrogen fertilizer rate and irrigation scheduling but not by its interaction effect.
**Conclusion:** Cabbage crop responded positively to optimum irrigation interval and increasing nitrogen fertilizer rate. Irrigation scheduling (6 days) and nitrogen fertilizer rate (92 kg/ha) may be fruitful for increment of cabbage yield and further research needs to combine another nitrogen fertilizer rate and combining effect of nutrients with phosphorous, potassium and other nutrients through irrigation interval.

**Keywords:** Yield, water use efficiency, nitrogen recovery.

**How to cite this article**: Terefa F (2021). Performance evaluation of cabbage (*Brassica oleracea* L.*Var.Capitata)* with irrigation scheduling and nitrogen fertilizer. J. Agri. Res. Adv. 03(01): 01-11.

## Introduction

Cabbage (*Brassica oleracea* var. *capitata* L.) belongs to the family cruciferae. It originated from wild non-headed type 'cole wart' (*Crambe cordifolias*) from Western Europe and Northern Shore of Mediterranean (Semuli, 2005). Cabbage is an excellent source of vitamin C and vitamin K, containing more than 20% of the Daily Value (DV) for each of these nutrients per serving (USDA, 2014).

Total world production of all brassicas for calendar year 2012 was 70,104,972 metric tons (68,997,771 long tons; 77,277,504 short tons). The nations with the largest production were China, which produced 47 percent of the world total and India, which produced 12 percent. China and India used a surface area of 980,000 hectares (2,400,000 acres) and 375,000 hectares (930,000 acres).



Area, production and yield of head cabbage in Ethiopia in 2015/2016 were 7,197.70 hectares, 463,17.72tons and 6.45 tons/ha, respectively, in Jimma area, production and yield of head cabbage was 143.40 hectares,10,11.84tons and 7.1ton/ha(CSA, 2016).

In Ethiopia, where the amount, timing and distribution of rain fall are irregular, use of irrigation would significantly improve and raise the level of production (Haile, 2014). The amount of water required by plants and the timing of irrigation are governed by prevailing climatic conditions, crop and stage of growth, soil moisture holding capacity and the extent of root development as determined by crop type, stage of growth and soil (Kadyampakeni, 2013).

Irrigation scheduling is a critical management input to ensure optimum soil moisture status for proper plant growth and development as well as for optimum yield, water use efficiency and economic benefits. Therefore, it is essential to develop irrigation

scheduling strategies under local climatic conditions to utilize scarce water resources efficiently and effectively (De Fraiture et al., 2010).

Cabbage has high requirements for all nutrients, especially nitrogen. Cabbage demands 130 to 310 kg/ha nitrogen for achieving high yield (Lešić et al., 2004, Sanderson and Ivany, 1999) and according to Richard et al. (2016) 375kg/ha nitrogen fertilizers gave maximum head yield. Nitrogen is important in the formation of chlorophyll and is also a component of proteins.

During winter season Farmers of Jimma area irrigate their crop land on average once per week. These are done if there is no rain fall and if the environmental condition is warm and dry. According Extension workers of Jimma Zone, 2015 says that farmers apply fertilizer, which is not recommended and most of them do not apply fertilizer to cabbage crops, other farmers apply different farmyard manure, cow dugs and different crop residues, which is collected from their houses. The area cultivated by cabbage in Jimma zone is 23,938ha.

Irrigation scheduling is one of the factors that influence the agronomic and economic viability of small farms. The use of animal manure and crop residues for fuel and erosion coupled with low inherent fertility are among the main causes for decreasing soil fertility (Taye et al., 1996; Tilahune et al., 2007). Jimma is the area with high rain fall. But, during winter season rain fall of the area is erratic and cannot fulfill crop requirements. In summer season the rain fall is high and cabbage is very susceptible for different diseases as well as the high amount of water causes splitting the cabbage head. Considering the facts, the present investigation was undertaken based to analyze effect of irrigation schedules and optimum water application based on crop water requirements, to identify effects of different levels of nitrogen fertilizer on growth and production of cabbage crop and to determine the optimum amount of water and nitrogen rate for cabbage production.

## Materials and Methods

*Description of Study Area*

The experiment was carried out at Buyo Kacham kebele (13.50$^0$N latitude and 38.24$^0$ E, Seka Woreda, Jimma Zone, on farmer's farm from November 10, 2015 up to March 10, 2016. Seka Chekorsa district is located at 375 km South West of Addis Ababa. It is situated at an altitude of 2000 meters above sea level. The district receives rainfall, about 1543.5mm per annum. The average minimum and maximum daily temperatures of the area are 8.1$^0$C and 30.5$^0$C, respectively. The characteristic of the soil is clay loam soil (Table 1). Generally, this soil is fertile for cabbage production.

Table 1. Physical and chemical properties of soil at the experimental site

| Parameters | Soil properties |
|---|---|
| % OM | 7.40 |
| % Total Nitrogen | 0.37 |
| pH | 7.6 |
| Available P in ppm | 6.51 |
| Texture | |
| % sand | 13.50 |
| % silt | 32.00 |
| % clay | 54.50 |
| Class | Clay Loam |
| Field Capacity (%) (0.33bar) | 40.22 |
| Permanent Wilting Point (%) (15 bar) | 22.83 |

*Experimental Materials:* The superior quality and high yielding cabbage Copenhagen variety was used. It was the most popular and reliable early round headed cabbage.

*Experiment Design:* The field trial was established in a factorial experiment as Randomized Complete Block Design (RCBD) with three replications. Sowing was done on 10, November 2015 in Jimma, Seka Chekorsa Woreda and the experiment was started after transplanting to the main field. Two factors were considered in this experiment, these were irrigation scheduling and nitrogen fertilizer rate. By using cropwat version 8.0 software, we estimated the amount of water required by cabbage crop to be 469.1mm $ET_c$. But, the area received 260.9 mm during the crop growing season. To fill the amount of water required by the crop, the difference, 208.2 (469.1 – 260.9 = 208.2, Table 2) was supplied as irrigation on three, six and nine days' interval. Based on this calculation, the crops received 11.73, 23.46 and 35.19 mm, respectively for each irrigation schedules.

The second factor which was nitrogen fertilizer was set at five levels, level 1 (0 N kg/ha), level 2 (23 N kg/ha), level 3 (46 N kg/ha), level 4 (69 N kg/ha), level five (92 N kg/ha). Depending on the availability of rain, farmers irrigate their cabbage once a week with a maximum of three liters per plant. As a practice, they also fertilize their farm land using different farm yard manure and/or residues. A combination of this farmer practice was used for comparison but was not included in the analysis. The experiment was set up as 3x 5 factorial arranged in Randomized Complete Blok Design (RCBD) with three replications and one farmer practice. Thus, there were 16 treatment combinations (Table 3). Spacing of 60 x 45 cm was used (Thamburaj and Sigh, 2004; Singh et al., 2004).

Table 2. Rain fall of Seka Chekorsa Woreda from 1995-2015 and 2015/2016

| Month | Rain fall (mm) |
|---|---|
| November | 117.7 |
| December | 104.4 |
| January | 29 |
| February | 98 |
| **Total** | **260.9** |

To calculate effective irrigation rainfall=$ET_c$-Rainfall (http://www.fao.org/docrep/s2022e/s2022e08.htm)

=469.1mm - 260.9mm

=208.2mm

The plot size was 2.40mx2.25 m= 5.4 $m^2$ each plot there was 20 plants. The two outer rows of the plot were treated as border while the two middle rows in each plot would regard as experimental rows. The distant between each plot was one meter and the distance between the block was two meter and the total experimental area covers 467.25$m^2$.

*Experimental Procedures*

*Crop:* Seedlings of the selected cabbage variety (*Brassica oleracea* L. var. *captata*) were raised in the seed bed one month before the actual transplantation (November 07, 2015). Thirty days after seeding (11 December, 2015), healthier and uniform seedlings were transplanted on a field at spacing of 60cm x 45cm.

Table 3. Treatments combination of irrigation schedules with fertilizer

| Days of application irrigation | Nitrogen fertilizer levels (kg/ha) | Treatment combinations |
|---|---|---|
| 3 days' interval | 0 | 3 days x 0 kg |
| | 23 | 3 days x 23 kg |
| | 46 | 3 days x 46 kg |
| | 69 | 3 days x 69 kg |
| | 92 | 3 days x 92kg |
| 6 days' interval | 0 | 6 days x 0 kg |
| | 23 | 6 days x 23 kg |
| | 46 | 6 days x 46kg |
| | 69 | 6 days x 69 kg |
| | 92 | 6 days x 92 kg |
| 9 days' interval | 0 | 9 days x 0 kg |
| | 23 | 9 days x 23 kg |
| | 46 | 9 days x 46 kg |
| | 69 | 9 days x 69 kg |
| | 92 | 9 days x 92 kg |
| Farmer practice | Farm yard manure and cow dung | Farm yard manure and cow dung with 7 days |

NB:- The amount of water used for 3 days interval is 11.73mm, for 6 days interval 23.46 mm, for 9 days interval 35.19 mm and for farmer practice 60 liters per plot.

*Fertilization:* Except on farmers' farm, each plot received 100kg/ha of triple supper phosphate (TSP). On farmer practice plot, well decomposed cow dung and manure 1000kg $ha^{-1}$ was applied. For nitrogen, urea fertilizer was applied in two splits, half at transplanting while the second half was applied 15 days after transplanting.

*Cultural operations*

After 17 days transplanting, first weeding was done and the viability and vigour of the seedlings were carefully observed. Infestation of aphids and African ball worm were found in the vegetative stage and was controlled by systematic insecticide, carotenoid that was applied at 0.5 liter $ha^{-1}$.

*Soil moisture monitoring:* Soil moisture was measured by tentiometer randomly at a depth of 20 cm before and after application of water every 3, 6 and 9 days from transplanting to harvesting.

*Calculation of irrigation requirement:* Irrigation requirement was calibrated according to the following equation Cropwat version 8.0 software and water was applied by using calibrated watering can to bring the water requirement of each interval days for the treatments The water requirement of cabbage is 469.1mm which is equal to 469.1liter per $m^2$ of land for all growing season. The area of each plot was 5.4$m^2$. The total water requirement of each plot was 2533.14liters for one plot. According to Cropwat version 8.0 software analysis the water needed for each day was 21.12litters. For 3 days' irrigation interval, the amount of water needed was 63.33litters, for six days' irrigation interval the amount of water needed was 126.66litters and for nine days' irrigation interval the amount of water needed is 189.99litters applied in each interval.

*Water use efficiency:* Water use efficiencies of cabbage were calculated according to Weiner et al. (2010)for evaluating the contribution of unit amount of water to crop yield. The computation was made using the following formula:

$$\text{Total water use efficiency (TWUE)} = \frac{\text{Total yield (kg/ha)}}{\text{Total water use (mm)}}$$

Or WUE=Y
ETc

*Harvest*: Harvest was done plot wise after judging the compactness of cabbage head. The crops were harvested on February 2, 10, 22 and 25, 2015 and the total weights of the crops of individual plots were recorded.

**Data collected**

*Growth parameters:* For growth parameter Head height (HH) (cm), Head diameter (HD)(cm), Outer leaf number (OLN) and Plant spread (PS) (cm) was recorded.

*Yield parameters:* For yield parameter Whole plant fresh weight (WPFW) (kg/plant), Head weight (HW) (kg/plant), Unmarketable yield (UMY) (t/ha), Marketable yield (MY) (t/ha), Total head yield (THY) (t/ha), Dry matter content (DM) (grams) and Harvest index (HI) was measured.

*Determination of Crop and Irrigation Water Requirement of Cabbage:* Crop water requirement of cabbage was determined using the Cropwat model based on the climatic data of the Jimma area, the crop grown (cabbage). Input data for the model was obtained from the National Meteorological Services Agency, Soil laboratory results and FAO publications. Twenty (20) years (1995 to 2015) meteorological data was used to estimate crop water requirement and the data were obtained from Jimma National Meteorological Station (Table 4). Calculations of water and irrigation requirements utilize inputs of climate, crop and soil data, as well as method of irrigation and rainfall data. Reference evapo-transpiration was calculated from temperature, humidity, sunshine and wind speed data, according to the FAO Penman-Monteith method (Allen et al., 1998).

Table 4. Climate data and reference evapo-transpiration at Jimma (1995 to 2014)

| Month | Rainfall (mm) | Maximum Temperatu ($^0$c) | Minimun Temperatur ($^0$c) | Relative humidity (%) | Wind speed (m $s^{-1}$) | Sun shine (h) | $ET_0$ (mı |
|---|---|---|---|---|---|---|---|
| January | 35.89 | 31.48 | 3.33 | 50.0 | 0.49 | 7.6 | 3.1 |
| February | 25.43 | 32.80 | 4.81 | 44.2 | 0.59 | 8.036 | 3.47 |
| March | 90.80 | 31.41 | 6.40 | 46.7 | 0.64 | 7.362 | 2.7 |
| April | 135.30 | 31.85 | 9.55 | 53.7 | 0.77 | 7.32 | 3.17 |
| May | 197.85 | 30.95 | 10.73 | 62.0 | 1.00 | 7.044 | 3.51 |
| June | 211.49 | 29.84 | 11.53 | 66.2 | 0.79 | 5.732 | 4.13 |
| July | 211.26 | 28.20 | 11.87 | 73.3 | 0.66 | 4 | 4.43 |
| August | 213.20 | 27.83 | 11.88 | 71.7 | 0.80 | 4.028 | 4.7 |
| September | 190.35 | 29.74 | 11.73 | 67.0 | 1.05 | 4.99 | 4.93 |
| October | 132.12 | 29.11 | 7.06 | 59.0 | 1.08 | 6.584 | 4.45 |
| November | 67.71 | 31.14 | 4.65 | 50.9 | 1.03 | 7.896 | 3.96 |
| December | 32.13 | 31.33 | 3.08 | 47.5 | 1.00 | 8.014 | 2.93 |
| **Total** | **1543.5** | | | | | | |
| **Average** | | **30.5** | **8.1** | **58** | **1** | **8.7** | **3.79** |

*Soil Sampling and Analyses Before and After Planting:* Soil samples were collected from Saka chekorsa woreda at 30cmdepth by diagonal pattering sampling technique before planting. These samples were composited and prepared for determination of soil chemical and physical properties involving soil texture, organic matter, organic carbon, pH, and amount of phosphorus (P) and nitrogen (N). The soil samples were cleaned from root and other dusts, air dried thoroughly, mixed and ground pass a 2-mm size sieve before laboratory analysis and analyzed at Jimma university college of Agriculture and veterinary Medicine soil laboratory.

Field capacity and permanent wilting point of the soil were analyzed by using pressure plate apparatus at 0.33bar pressure for field capacity and 15bar pressure for permanent wilting point.

*Plant Tissue Sampling and Analysis*

*Determination of N in cabbage*

Total N content was obtained after multiplying N concentration of the cabbage by total head yield.

Apparent recovery efficiency (ARE) (%) = (Nuf–Nu/Na) × 100

Where, Nuf is the N uptake of the fertilized treatment (kg) and Nu is the N uptake of unfertilized treatment (kg) (Albrizio and Todorovic et al., 2010).

*Statistical Analysis*

All data were examined subjected to analysis of variance using proc GLM (General Linear Model) procedure of SAS 9.3 software (SAS Institute Inc.2009). The means was compared with least significant difference (LSD) at 5% significance level.

## Results and Discussion

*Effects Irrigation Scheduling and Nitrogen Fertilizer Rate on the Growth of Cabbage Crop*

*Head diameter, head height, plant height and plant spread:* Nitrogen fertilizer rate by irrigation schedule significantly (P<0.001) affected head diameter, head height, plant height and plant spread parameter. The biggest head diameter 17.43cm was recorded at the treatments combination of 6 days' irrigation scheduling and 92kg $ha^{-1}$ nitrogen fertilizer (Table 5). The smallest head diameter (9.37cm) was observed at the treatments combination of 3 days irrigation interval and zero N levels. The size of head of cabbage is genetically controlled but the size of the diameter of the head is directly related with yield performance. Optimum days of irrigation scheduling and higher nitrogen fertilizer rate favored better nutrient uptake by encouraging better physiological activities and leading better plant growth and bigger head formation.

The highest head height (19.67cm) was observed at the treatments combination of 6 days' irrigation interval and 92kg $ha^{-1}$ of nitrogen fertilizer, the lowest (10.83cm) was at the treatments combination of 9 days' irrigation interval and without nitrogen fertilizer level (Table 5). This shows higher nitrogen fertilizer rate and optimum days of irrigation interval favored the head height of cabbage.

The interaction effect of irrigation scheduling and nitrogen fertilizer on plant height was highly significant (Table 5). The plants receiving highest dose of nitrogen and 6 days' irrigation scheduling had maximum height of 24.65cm which is statically similar with 69 kg $ha^{-1}$ nitrogen fertilizer and 6 days' irrigation scheduling. Plants receiving no nitrogen fertilizer but irrigated at 9 days' irrigation interval had the lowest plant height (16.57cm). But, this value was statically similar with the height of the plants observed at treatment combination of 23kg $ha^{-1}$ nitrogen and 9 days' irrigation interval.

Plant spread was significantly affected by interaction of nitrogen fertilizer rate and irrigation scheduling. The narrowest plant spread (24.46cm) was observed from plants grown at 0kg/ha nitrogen fertilizer rate and 3 days of irrigation scheduling interval (Table 5). Widest plant spread at higher nitrogen rate 92kg/ha and at 6 days of irrigation interval (38.77cm), is due to higher nitrogen levels favor the growth of plants leading to larger leaf area that cover the wider space.

*Outer leaf number:* Outer leaf number of cabbage means number of outer leaf none headed. Nitrogen fertilizer significantly affected outer leaf number but irrigation scheduling and interaction of nitrogen fertilizer and irrigation scheduling had no any significant effect on outer leaf number. The highest outer leaf number was recorded (18.86) on the control of nitrogen fertilizer which was not significantly different from outer leaf number 18.66, which was recorded at 23 kg $ha^{-1}$ of nitrogen fertilizer (Table 7). These results showed that number of non-wrapper leaves steadily decreased with increasing N concentration. Similar results were observed by Mustafa and Zohair (2013). According to these authors, application of N fertilizer, in successive amounts up to 350 kg $ha^{-1}$, to the growing cabbage plants, resulted in corresponding and significant decreases in the number of outer leaves.

*Effects Irrigation Scheduling and Nitrogen Fertilizer Rate on the Yield of Cabbage Crop*

*Dry matter, marketable and unmarketable yield, total head yield and whole fresh weight:* Nitrogen fertilizer rate by irrigation schedule significantly (P<0.001) affected dry matter, marketable yield, unmarketable yield, total head yield and whole fresh weight parameter.

Cabbage dry matter increased with increasing both nitrogen fertilizer and irrigation schedule. The highest dry matter (7.36%) was observed at the treatments combination of 92kg $ha^{-1}$ nitrogen fertilizer rate and 9 days' irrigation scheduling (Table 6). The lowest dry matter

(3.43%) was recorded at the treatment combination of 6 days' irrigation interval and 0kg $ha^{-1}$ nitrogen fertilizer which is similar with Mohammed (2004). The author found the highest dry matter content at a treatment combination of 15-day irrigation interval with 240 kg $ha^{-1}$ Nitrogen fertilizer rate and the lowest was recorded at 5 days irrigation interval and 0kg $ha^{-1}$ nitrogen fertilizer rate. This shows that with increasing nitrogen fertilizer rate and long days' irrigation schedules; the crops can get more sun light than the other days of irrigation schedules this facilitate photosynthetic rate of the plant in relation to the fertilizer.

The highest marketable yield (64.5t/ha) was recorded at the treatment combination of 92 kg/ha nitrogen fertilizer level and 6 days' irrigation interval (Table 6). On the other hand, the lowest yield (20.09t/ha) was obtained from cabbage grown without nitrogen fertilizer and 6 days' interval which was statically similar with 9 days irrigation interval without any nitrogen fertilizer application. Similar observation on cabbage marketable yield was also reported by Mohammed (2004). In this study, the highest marketable yield was recorded under 5 days' irrigation interval and 240 nitrogen fertilizer rate. This may be due to irrigation and nitrogen played a significant role in accelerating on vegetative growth of cabbage crops.

The lowest unmarketable yield (7t/ha) was recorded with the treatment combination of 92 kg/ha nitrogen fertilizer level and 6 days' irrigation scheduling whereas the highest unmarketable yield (30.91 t/ha) was recorded with the treatment combination of 6 days' irrigation scheduling without any nitrogen application (Table 6). This could be due to the synergic effect of irrigation scheduling and nitrogen fertilizer level missing of nitrogen application decrease the yield.

The highest total yield (71.52tone/ha) was recorded under the treatment combination 6 day's irrigation interval and 92 kg $ha^{1}$ nitrogen fertilizer which was significantly higher than all other treatments (Table 6, Fig.2). The lowest yield of 35.91 tone/ha was recorded under the treatment combination of 9 days' irrigation interval and 23 nitrogen fertilizer which was statically similar with the treatment combination of nine days' irrigation scheduling and 0 kg $ha^{-1}$ nitrogen fertilizer. From this study, it has been found that application of both nitrogen and irrigation scheduling are indispensable increasing cabbage yield. Because, there is higher uptake of nutrients (Bafna et al., 1993), and excellent soil-water-air relationship with higher oxygen concentration in the root zone (Gornat et al., 1973).

Table 5. Interaction effects of nitrogen fertilizer rates and irrigation scheduling on growth parameter, water use efficiency of cabbage and nitrogen recovery

| Treatments | | HH (cm) | D (cm) | PS (cm) | PH (cm) | WUE (kg/ha) | NRe (%) |
|---|---|---|---|---|---|---|---|
| Irrigation (days) | Nitrogen fertilizer (kg ha | M | e | a | | n | s |
| 3days | 0 | 13.63 | 9.4 | 24.46 | 18.3 | 44.09 | ---- |
| | 23 | 14.07 | 11.69 | 27.23 | 19.17 | 55.8 | 81.8 |
| | 46 | 14.43 | 11.59 | 32.16 | 19.23 | 60.83 | 72.2 |
| | 69 | 14.53 | 12.61 | 33.65 | 20.02 | 103.86 | 65.45 |
| | 92 | 15.23 | 14.57 | 35.12 | 21.07 | 106.51 | 60.9 |
| 6 days | 0 | 13.37 | 11.12 | 27.61 | 21.64 | 71.77 | ---- |
| | 23 | 14.55 | 12.69 | 29.03 | 20.6 | 74.21 | 44.58 |
| | 46 | 17.47 | 13.12 | 32.22 | 20.67 | 121.93 | 54.72 |
| | 69 | 18.53 | 14.22 | 33.89 | 23.87 | 133.51 | 56.95 |
| | 92 | 19.67 | 17.43 | 38.77 | 24.65 | 152.47 | 44.59 |
| 9days | 0 | 10.83 | 11.45 | 27.43 | 16.57 | 48.82 | ---- |
| | 23 | 14.53 | 11.99 | 29.06 | 16.92 | 55.95 | 89.9 |
| | 46 | 14.9 | 12.72 | 30.66 | 19 | 89.08 | 89.4 |
| | 69 | 15.73 | 11.78 | 31.81 | 20.38 | 123.01 | 86.9 |
| | 92 | 16.83 | 13.53 | 34.11 | 21.15 | 131.64 | 87.8 |
| Mean | | 15.22 | 12.65 | 31.15 | 20.21 | 14.07 | 56.69 |
| CV% | | 1.45 | 2.29 | 2.39 | 2.46 | 14.06 | 6.9 |
| LSD | | 0.3 | 0.4 | 1.25 | 0.85 | 1.87 | 6.52 |

HH=head height, D=diameter, PS= Plant spread, OLN=outer leaf number, PH =plant height, WUE= water use efficiency, NRe= nitrogen recovery

The interaction effect of irrigation interval and nitrogen level on whole fresh weight per plant was also highly significantly (Figure 2). The highest whole fresh weight 5.73kg was recorded at the three days irrigation schedules and an application of 92 kg/ha nitrogen fertilizer rate. The plants grown under the nine days irrigation interval without any fertilizer gave the lowest whole fresh weight (1.67kg/plant) suggesting that the plants were starved of N due to lack of adequate N uptake through irrigation water. On the other hand, the residual soil moisture that applied in three days' irrigation interval associated with the added nitrogen might be utilized efficiently to produce relatively higher whole fresh weight of cabbage as compared to the plots where no or minimum nitrogen was added. Similar results were also reported by Kadyampakeni (2013). They found that the yields of cabbage increase with increasing rates of

applied fertilizer and with applied farm yard manure but optimum irrigation with a moderate increase in fertilizer rate gave the highest yield.

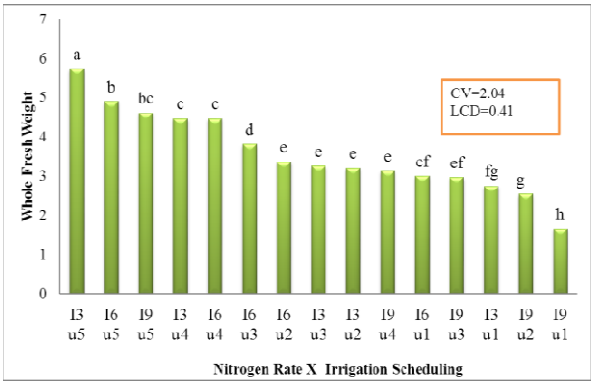


Fig 1. Interaction effects of nitrogen rate and irrigation scheduling on whole fresh weight
(I3U1=3 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I3U2=3 days irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I3U3= 3 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I3U4= 3 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I3U5=3 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I6U1=6 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I6U2= 6 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I6U3= 6 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I6U4= 6 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I6U5=6 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I9U1=9 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I9U2= 9 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I9U3= 9 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I9U4= 9 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer and
I9U5= 9 days' irrigation scheduling and 92 kg/ha nitrogen fertilizer)

*Head weight :* Cabbage head weight was significantly (*P<0.05*) affected by the interaction between nitrogen fertilizer and irrigation scheduling. The highest head weight (3.28kg/plant) was obtained at the treatment combinations of 92 kg/ha nitrogen fertilizer rate and 6 days' irrigation scheduling (Fig. 3). But, the result was not statistically different from a treatment combination of 92 kg/ha nitrogen fertilizer and 3 days' irrigation intervals (3.23 kg/plant) (Table 6). The lowest head weight (1.12kg/plant) was found at the treatment combination of no nitrogen fertilizer and 9 days' irrigation interval. This was also not statistically significant with zero nitrogen fertilizer level and 3 days' irrigation interval as well as with 23 kg $ha^{-1}$and 3 days' irrigation interval. These results are similar with the results reported by Mohammed (2004). Since, cabbage is heavy feeder for both nitrogen fertilizer rate and water, high amount of water and nitrogen fertilizer rate increase weight of head cabbage.

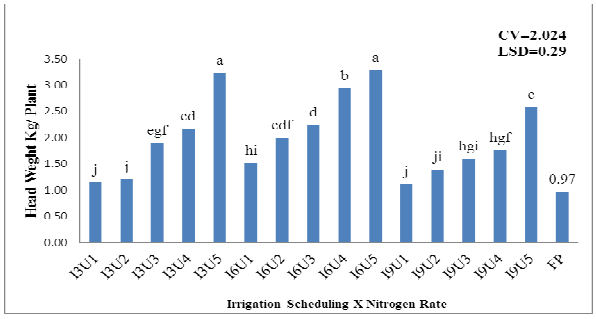


Fig 2. Effect of interaction between nitrogen fertilizer rate and irrigation scheduling on head weight of cabbage

(I3U1=3 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I3U2=3 days irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I3U3= 3 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I3U4= 3 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I3U5=3 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I6U1=6 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I6U2= 6 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I6U3= 6 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I6U4= 6 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer,
I6U5=6 days irrigation scheduling and 92 kg/ha nitrogen fertilizer,
I9U1=9 days irrigation scheduling and zero kg/ha nitrogen fertilizer,
I9U2= 9 days' irrigation scheduling and 23 kg/ha nitrogen fertilizer,
I9U3= 9 days' irrigation scheduling and 46 kg/ha nitrogen fertilizer,
I9U4= 9 days' irrigation scheduling and 69 kg/ha nitrogen fertilizer and
I9U5= 9 days' irrigation scheduling and 92 kg/ha nitrogen fertilizer)

*Harvest index*

Cabbage harvest index was highly significantly (P<0.001) affected by the main effect of nitrogen

fertilizer rate and irrigation schedules. The interaction of nitrogen fertilizer level and irrigation schedules did not affect harvest index.

The highest harvest index was recorded on the 92kg ha$^{-1}$ (60%). The lowest was observed on the no nitrogen fertilizer (36.19%) (Table 7). This result is similar with the finding of Semuli (2005), who showed that the ratio of trimmed head to untrimmed head was higher at higher nitrogen level than lower nitrogen level. This shows that harvest index increased with increase in level of nitrogen fertilizer and nitrogen rate is clearly important for the allocation of assimilates to the harvestable part of cabbage crops. Sarke et al. (2002) also reported that higher harvest index was obtained from the higher rate of fertilizer.

Again, irrigation scheduling had highly significant effect on harvest index of cabbage crops. The highest harvest index (60.7%) was observed at 6 irrigation scheduling (Table 7). The lowest harvest index (48.58%) was recorded at 3 days' irrigation scheduling. implying both short interval and long interval of irrigation does not help to get good harvest index.

Table 6. Interaction effects of nitrogen fertilizer rates and irrigation scheduling on yield parameter of cabbage

| Treatments | | | | | |
|---|---|---|---|---|---|
| Irrigation (days) | Urea (kg ha | UMY(t/ha) | MY(t/ha) | TY(t/ha) | DRM(g) |
| 3days | 0 | 17.28 | 21.73 | 39.02 | 4.09 |
| | 23 | 21.54 | 21.36 | 42.9 | 4.64 |
| | 46 | 19.60 | 26.64 | 46.25 | 4.72 |
| | 69 | 20.62 | 28.72 | 49.34 | 5.04 |
| | 92 | 12.05 | 38.19 | 50.25 | 5.52 |
| 6 days | 0 | 30.91 | 20.09 | 51 | 3.43 |
| | 23 | 26.33 | 36.79 | 63.12 | 3.83 |
| | 46 | 12.53 | 44.04 | 56.56 | 4.31 |
| | 69 | 10.68 | 52.23 | 62.92 | 4.80 |
| | 92 | 7.00 | 64.5 | 71.52 | 5.02 |
| 9days | 0 | 13.62 | 22.61 | 36.24 | 4.44 |
| | 23 | 12.51 | 23.41 | 35.91 | 5.11 |
| | 46 | 11.9 | 40.99 | 52.89 | 5.8 |
| | 69 | 11.2 | 46.17 | 57.37 | 6.64 |
| | 92 | 10.27 | 51.48 | 61.75 | 7.36 |
| Mean | | 15.87 | 35.93 | 51.8 | 4.98 |
| CV% | | 12.11 | 4.65 | 4.94 | 2.05 |
| LSD | | 2.99 | 1.74 | 3.17 | 1.56 |

HW=head weight, UMY=unmarketable yield, MY=marketable yield, TY=total yield, WFW=whole fresh weight, DRM=dray matter, HI, harvest index.

*Effects of Irrigation and Nitrogen on Nutrient Content of Cabbage*

*Total N content:* The total nitrogen content of cabbage was affected by both irrigation scheduling and nitrogen fertilizer rate. Irrigation scheduling had significant influence on total nitrogen content of cabbage crops. The maximum nitrogen content of 3.33% was recorded under the six days of irrigation scheduling (Table 7). The lowest value 2.28% of nitrogen content found in nine days' irrigation scheduling which is statically similar with 3 days' irrigation schedules (2.31%). Better rooting system and plant growth under optimum days of irrigation interval might have enabled the plant to explore more nitrogen. Logically the plant nitrogen content increase significantly with each of nitrogen application, thus the resulting the higher nitrogen content 3.44% was under the highest nitrogen level (92kg). The minimum amounts of nitrogen content of 1.71% were found in plots where no nitrogen fertilizer was added. The interaction of nitrogen fertilizer level and irrigation schedules did not affect leaf nutrient concentrations. The findings were in line with the results reported by Padem and Alan (1995).

*Nitrogen recovery:* Nitrogen recovery of cabbage crops as influenced by irrigation scheduling and nitrogen fertilizer rate. The nitrogen recovery in cabbage is shown in table 6 and significantly influenced by interaction effect of nitrogen fertilizer rate and irrigation schedules ($P<0.001$).

The highest nitrogen recovery efficiency (89.9%) was obtained at treatment combination of 23kg ha$^{-1}$ nitrogen fertilizer rate and 9 days irrigation schedules which is statically similar with 46 kg ha$^{-1}$ nitrogen fertilizer rate and 9 days irrigation schedules (89.4%), whereas the lowest nitrogen recovery (44.58%) was recorded at treatment combination of 23kg ha$^{-1}$ nitrogen fertilizer rate and 6 days irrigation schedules which is statically similar with 92kg ha$^{-1}$ nitrogen fertilizer rate and 6 days irrigation schedules(44.59%). This shows that the quantity of nitrogen recovered in the cabbage heads was small relative to the quantity of N applied as fertilizer with optimum days of irrigation scheduling.

*Water Use Efficiency:* The interaction effect of nitrogen fertilizer rate and irrigation scheduling significantly ($P<0.05$) affected water use efficiency of cabbage. The highest water use efficiency 152.47kg ha$^{-1}$mm$^{-1}$ was recorded at the 6 days' irrigation scheduling and 92kg ha$^{-1}$nitrogen fertilizer (Table 5). The smallest water use efficiency (44.09kg ha$^{-1}$mm$^{-1}$) was at irrigation interval of 3 days and control of nitrogen fertilizer which was statically similar with 9 days'

irrigation scheduling and control nitrogen fertilizer rate.

Table 5. Effect of irrigation scheduling and nitrogen fertilizer on total nitrogen rate, outer leaf number and harvest index parameters of cabbage

| Treatments | Total nitrogen (%) | Outer leaf number | Harvest index |
|---|---|---|---|
| Nitrogen fertilizer rate (kg/ha) | | | |
| 0 | 1.71 | 18.86 | 50.32 |
| 23 | 2.29 | 18.66 | 53.96 |
| 46 | 2.66 | 18.4 | 56.93 |
| 69 | 3.09 | 18.21 | 56.87 |
| 92 | 3.44 | 17.93 | 60.17 |
| LSD (5%) | 0.19 | 0.67 | 4.35 |
| CV (%) | 2.05 | 2.04 | 4.63 |
| Irrigation schedulings | | | |
| 3 days | 2.31 | 18.75 | 48.58 |
| 6 days | 3.33 | 18.57 | 60.7 |
| 9 days | 2.28 | 18.66 | 53.02 |
| LSD (5%) | 0.15 | 0.5 | 3.38 |
| CV (%) | 2.04 | 2.04 | 4.3 |

Means followed by different letters per column differ significantly (P < 0.05) as established by LSD test.

The higher water use efficiency might be due to the lower rate of water loss through evaporation from soil surface. Michael (1978) also noted that nutrient and irrigation management practices can increase WUE by increasing crop yield. Similar results were supported by Khaled (2006) who reported that the highest WUE of Canola (*Brassica napus* L.) value was observed with the irrigation interval of 14 days, particularly in case of application the highest N rate (180 kg N $ha^{-1}$). Lower WUE with increasing irrigation interval more than 14 days (21 and 28 days) could be due to the decrease in yield with increasing the drought period.

*Mean comparison of Farmer Practice with Recommended Treatments:* To compare farmer practice with recommended which is 6 days' irrigation interval 92kg $ha^{-1}$ nitrogen fertilizer rate by using paired t-test SAS software shown in the table 8. Both Farmer practice and the recommended result shows statically different. The means of head height, head diameter, plant spread, outer leaf number, whole fresh weight and head weight, 3.92, 2.57, 855.8, 3.09, 2.49 and 2.13, respectively. On average, the scores from farmer practice were lower than these results. On the other way comparing farmer practice with three days' irrigation scheduling with 92kg/ha nitrogen fertilizer and nine days irrigation scheduling with 92 kg/ha nitrogen fertilizer the farmer practice is lower by 75.67 and 70.78 means. This was because application of fertilizer and water optimization was not the norm in farmers practice and thus, neither environmentally nor economically feasible.

Table 6. Mean Comparison of farmer practice with 6 day irrigation scheduling and92kg/nitrogen fertilizer rate

| Parameter | Means difference | t- value | Pr > \|t\| |
|---|---|---|---|
| Head height (cm) | -3.92 | -65.18 | 0.0002 |
| Diameter (cm) | -2.57 | -7.39 | 0.017 |
| Plant spread($cm^2$) | -855.8 | -15.88 | 0.007 |
| Outer leaf number(no) | -3.09 | -5.53 | 0.0312 |
| Whole fresh weight(kg) | -2.49 | -7.49 | 0.0123 |
| Head weight(kg) | -2.13 | -47.11 | 0.005 |

*Nitrogen after Harvest in the Soil*

The amount of nitrogen left in the soil after harvest was very highly significantly (P<0.001) affected by main effects nitrogen fertilizer level and irrigation scheduling.

Table 7. Laboratory soil nitrogen analysis

| Irrigation (days) | Nitrogen Fertilizer rate (kg $ha^{-1}$) | Percentage of nitrogen left in the soil after harvest |
|---|---|---|
| 3 | 0 | 0.35 |
| 3 | 23 | 0.36 |
| 3 | 46 | 0.37 |
| 3 | 69 | 0.37 |
| 3 | 92 | 0.38 |
| 6 | 0 | 0.31 |
| 6 | 23 | 0.32 |
| 6 | 46 | 0.34 |
| 6 | 69 | 0.37 |
| 6 | 92 | 0.42 |
| 9 | 0 | 0.31 |
| 9 | 23 | 0.35 |
| 9 | 46 | 0.38 |
| 9 | 69 | 0.42 |
| 9 | 92 | 0.45 |
| | Farm yard manure and cow dung with 7 | 0.36 |
| LSD (5%) | | 0.03 |

Combined effect of nitrogen fertilizer level and irrigation scheduling also affected amount of nitrogen left in the soil (Table 9). The highest amount of nitrogen (0.45%) left in the soil was recorded at higher nitrogen fertilizer level (92kg/ha) and nine days' irrigation interval whereas the lowest (0.31%) was recorded at lower or zero level of nitrogen fertilizer and nine days' irrigation scheduling (Table 9) which is

statically similar with 6-day irrigation interval and control nitrogen fertilizer. Increasing nitrogen rate from 0 to 92 kg/ha increased soil total nitrogen by 100%. The nitrogen left in the soil at no nitrogen fertilizer rate and 23 kg/ha were lower when compared with pre-planting nitrogen (0.37%) but increases in the case of 46, 69 and 92kg/ha of nitrogen rate. Increasing nitrogen and plants inability to uptake as result of limited soil water has probably increased post-harvest total soil nitrogen. The current finding agrees with the report of Frezer (2007) that reported increasing nitrogen level increased post-harvest soil total nitrogen. If water is not optimized for the nutrient to be taken up, total nitrogen builds up in the soil. Salo (1999) also reported that nitrogen after harvest tends to increase with increasing amount of fertilizer applied. This means a loss if N and water application are not synchronized and nutrient is taken up there could be potential danger for environment or it might be washed to ground water.

## Conclusion

It was concluded that cabbage crop responded positively to optimum irrigation interval and increasing nitrogen fertilizer rate. The farmer of the studied area should be used 6 days' irrigation scheduling and 92 kg/ha nitrogen fertilizer rate for their increment of cabbage yield, the experiment was worked by water cane to measure the amount of water but the farmer uses by their own suitable irrigation method for application of water. The experiment was conducted at one location for only one season; further investigations may be needed to be carried out at different seasons of the year, location, soil type, cabbage varieties and different farmer practice to come up with precise and comprehensive recommendation. And, further research need to combine another nitrogen fertilizer rate and with combining effect nutrients with phosphorous, potassium and other nutrients with this irrigation interval.

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